Friction Noise Caused by Fretting and its Prevention

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Background and Aim of this Study

Background

- Under the micro reciprocating motion, or micro oscillating motion like "fretting",
  - →It may be accompanied by friction noise
  - →preventing or reducing the friction noise could be important for designers, operators, and engineering
- Friction noise generated at the actual machine element
  - →Generally grease lubricated, but could not be prevented adequately
  - →It's attributable to the mystery of its mechanism (namely, no report)

Aim

1. To clarify the mechanism of the friction noise caused by fretting
2. To get a guideline of its prevention

Composition of this Study

Chapter 4 | Measurement of ECR
- ECR and wear scar
- Influence of relative stroke and RH
- ECR under various Lubricants

Chapter 6 | Vibration Analysis
- Analysis model
- Derivation of analytical solution
- The case of sine wave input
- The case of multiple type input
- Time response against input wave

Chapter 5 | Under Dry Condition
- Relation between friction noise, and friction & sliding behavior
- Influence of load, frequency, and relative stroke
- Influence of RH, and atmosphere
- Understanding the contacting condition by ECR measurement
- Observation of wear scar

Chapter 11 | Conclusion

◎Conclusion

Chapter 10 | Discussion

◎Clarification of the Mechanism

◎Guideline for the Prevention

Chapter 7 | Under Lubricated Condition
- Friction noise under grease lubrication
- Influence of amount of grease, stroke, and RH
- Direct observation by optical microscope
- Mechanism of friction noise
- Fretting mechanism under grease lubrication

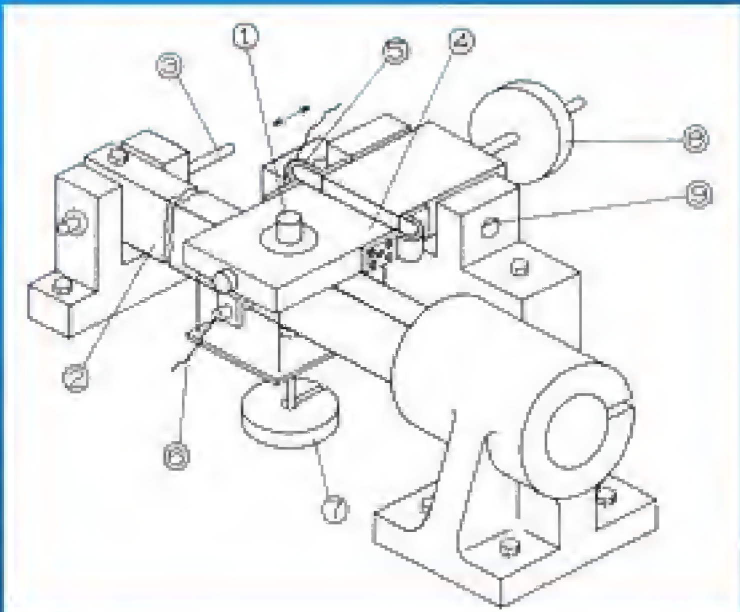
Effect of Shot Peening

Initial Runnin-in Property

Chapter 8 | Effect of Surface Texturing
- Patterns of surface micro texturing
- Change of coefficient of friction
- Influence of normal load, and stroke
- Influence of oxide film, and extreme pressure additive
- Contacting stiffness of micro texturing surface

Chapter 9 | Surface Modification of Hard Coating
- Partial contacting wear test
- Effect of plating on initial running-in
- Observation of partial contacting wear scar
- Mechanism of running-in for hard coating

Overview of fretting wear apparatus



① Upper specimen

② Cantilever

③ Driving arm

④ Upper specimen holder

⑤ Leaf spring

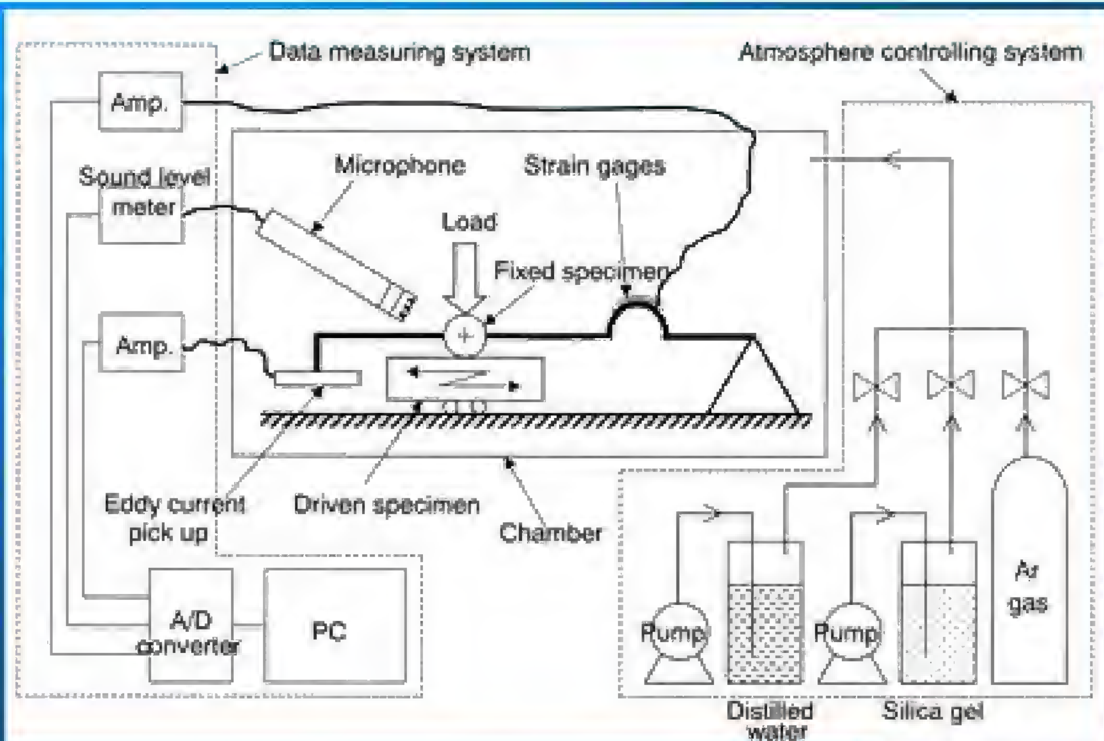
⑥ Eddy current pickup

⑦ Dead weight

⑧ Counterweight

⑨ Anvil

Apparatus



Schematic diagram of the fretting rig

Test apparatus

Specimens

Table Specimens

Fixed specimen (Upper specimen)	0.45% carbon steel quenched Hv730, Ry1.0 μm
Driven specimen (Lower specimen)	Mild steel Hv240, Ry1.0 μm

Fretting test

Table Experimental conditions

Fretting stroke	25～400 μm
Normal load	19.6N
Atmosphere	Laboratory air, Grease lubrication
Test duration	Up to 10^6 cycles
Frequency	7.3Hz
Temperature	294±2K
Relative humidity	23～80%RH
Data sampling frequency	5kHz (4096 data)
Configuration	Crossed cylinders, Ball on plate

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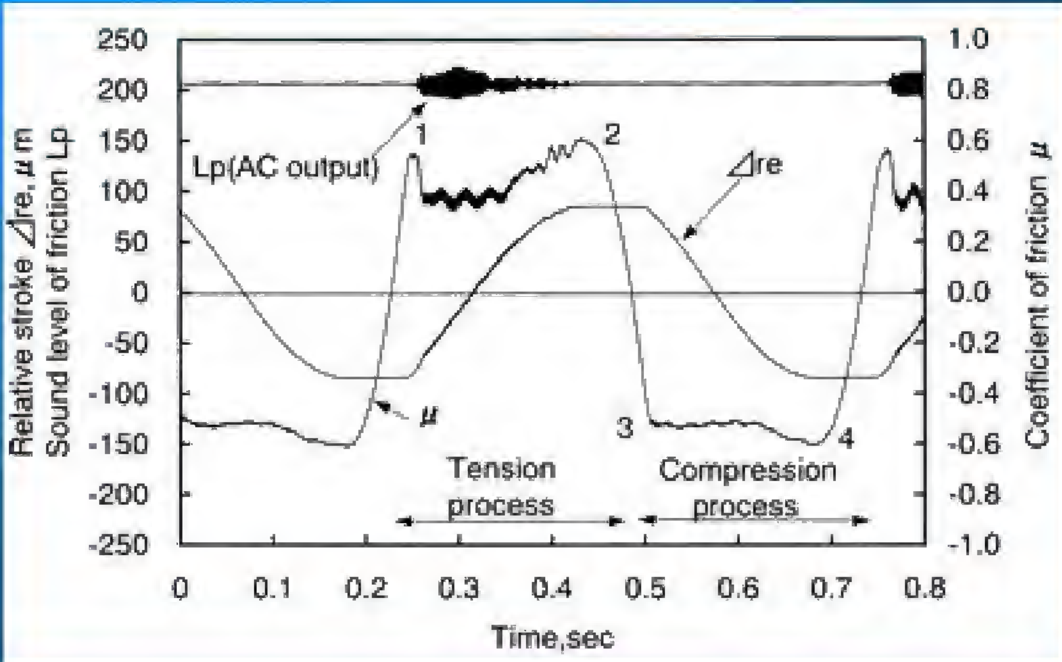
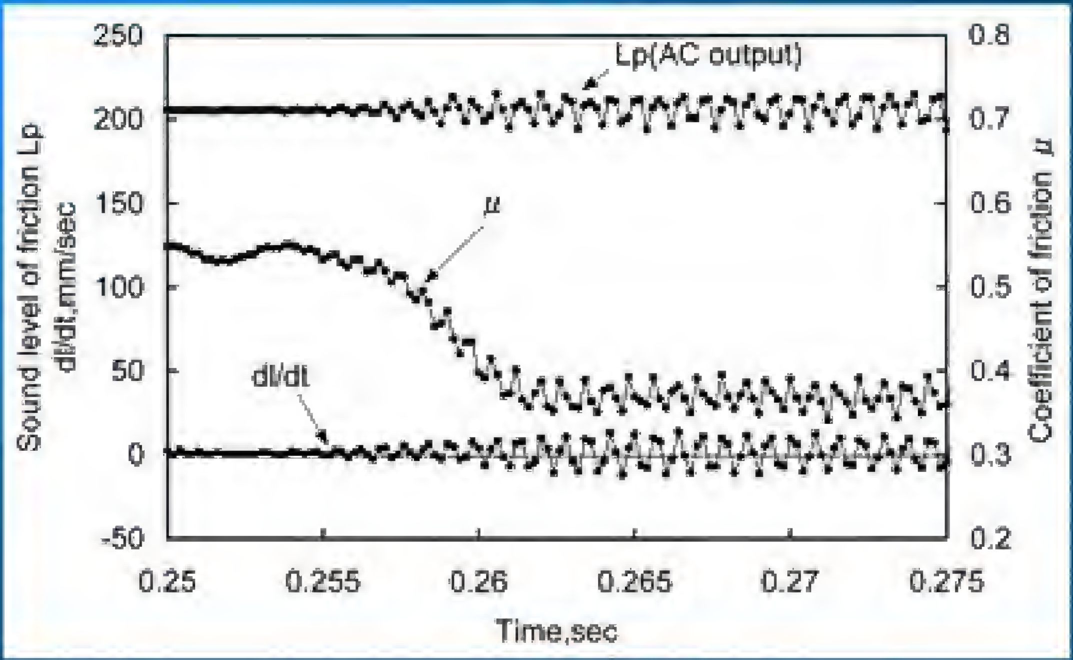
Measurements and analysis of waveforms



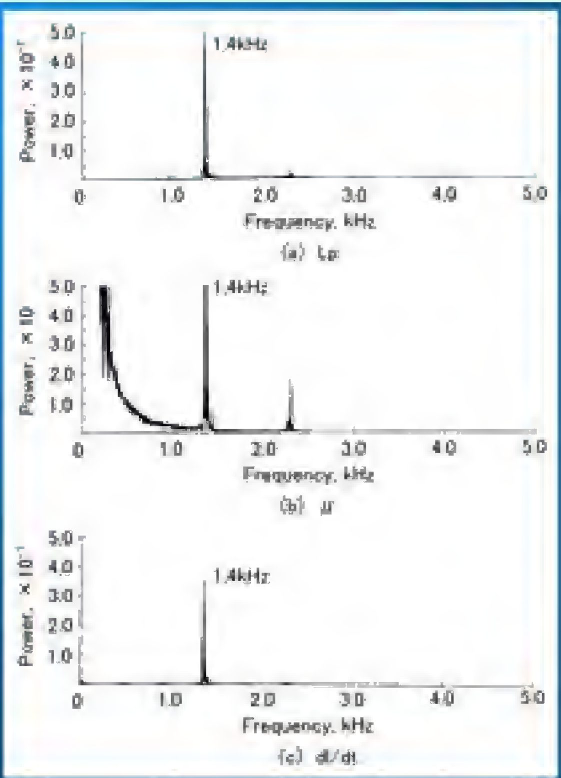
Typical example showing waveforms of friction noise (AC output), coefficient of friction μ, and relative stroke Δre.

Measurements and analysis of waveforms



Magnified time axis around the beginning of tension process

Measurements and analysis of waveforms



FFT analysis of Lp, μ, and dI/dt

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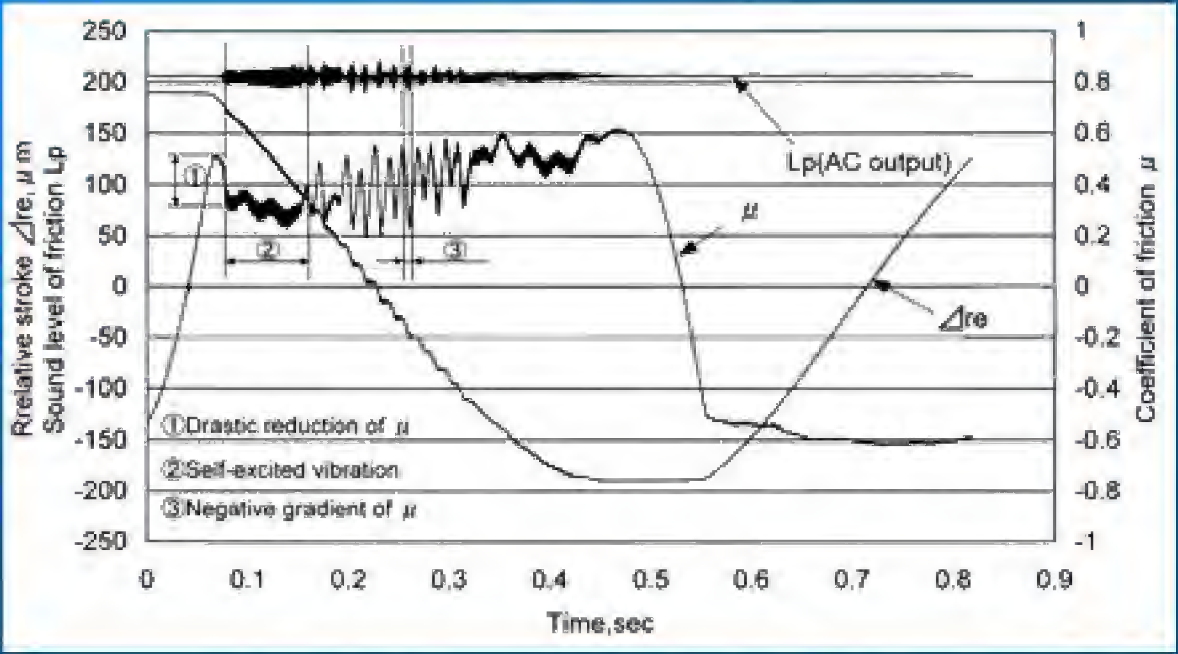
Measurements and analysis of waveforms



Another typical example of waveforms;

Stroke of 401 μm, 30%RH, 1Hz

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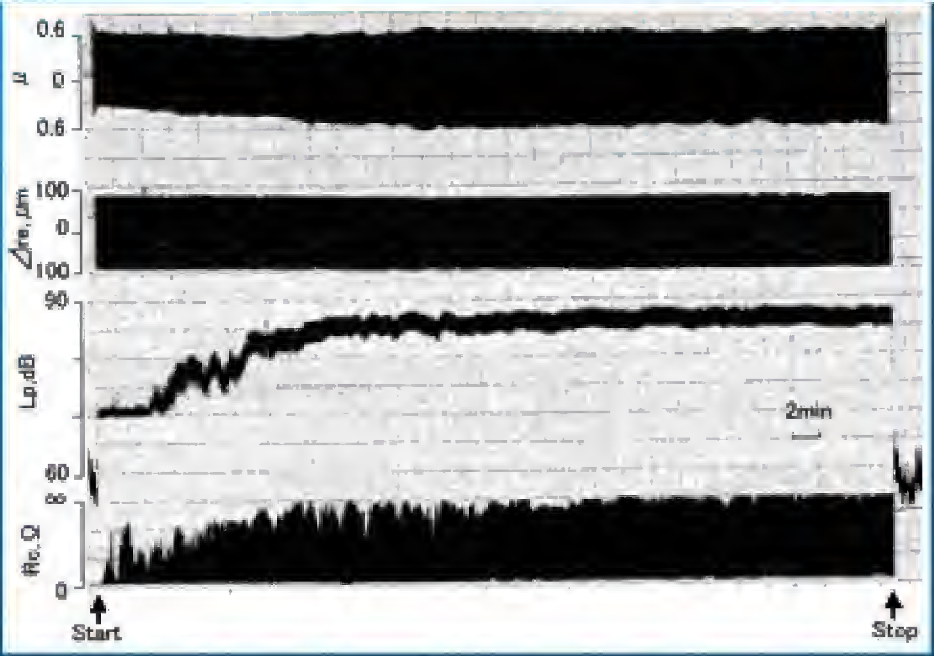
Measurement of electrical contact resistance Rc



Electrical contact resistance Rc and friction noise Lp (DC output) together with μ and ⊿re versus fretting cycles; Stroke of 191 μm, 46%RH, 7.2Hz, 25000cycles

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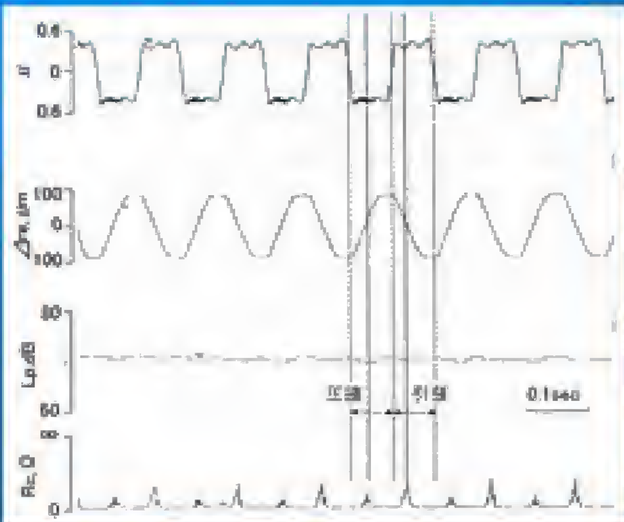
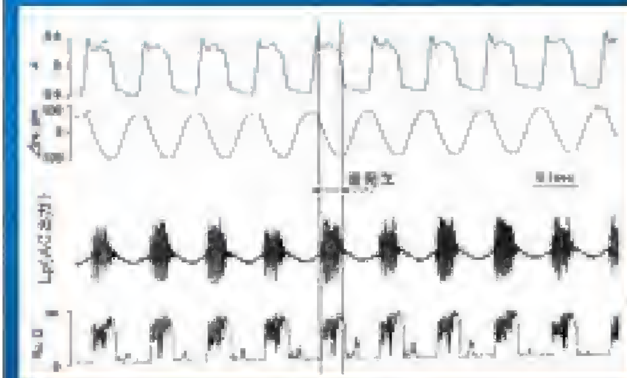
Measurement of electrical contact resistance Rc



Precise Rc and Lp (DC output) before the occurrence of friction noise; after 300 cycles



Precise Rc and Lp (AC output) after the occurrence of friction noise; after 25000 cycles

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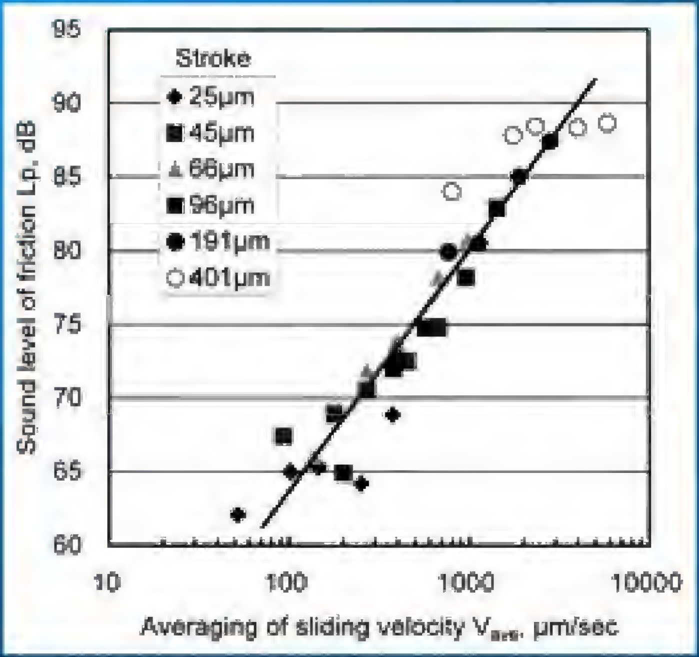
Influence of fretting stroke and frequency



Lp (dB value) plotted against V_{ave}; 30% RH, 25000 cycles

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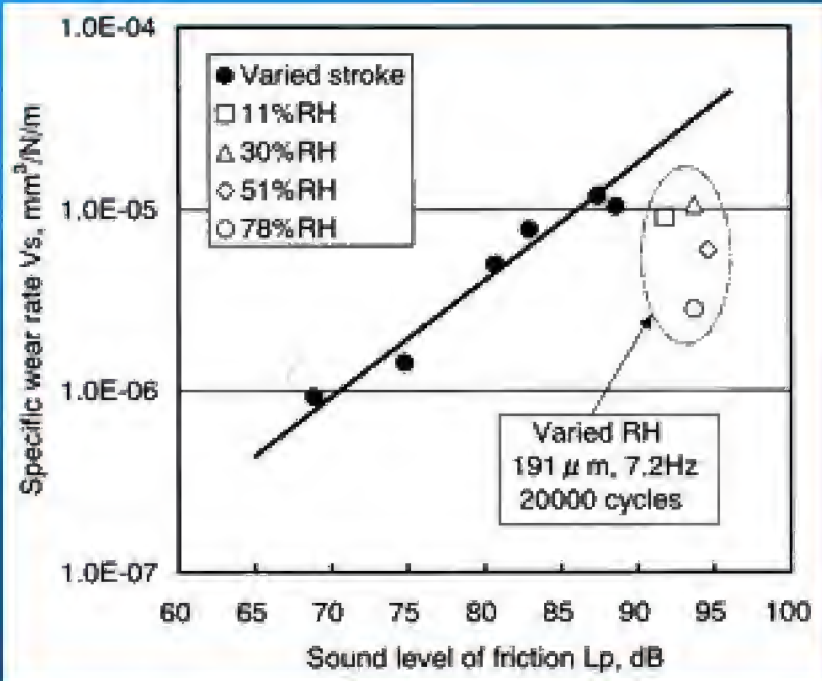
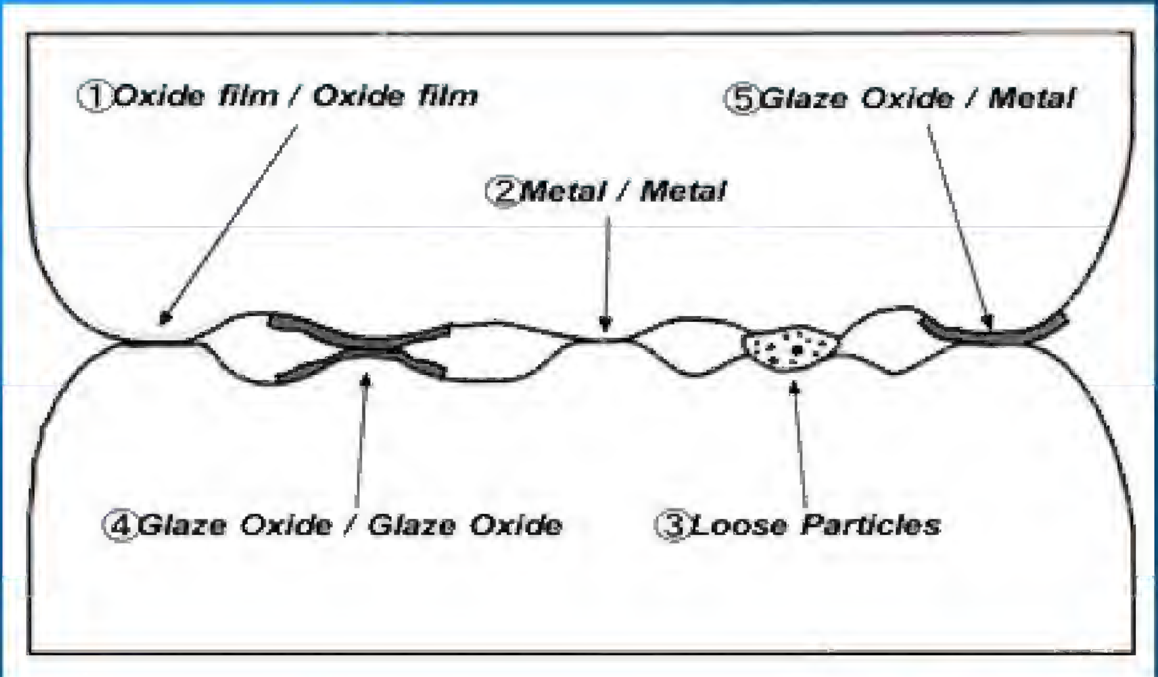
Specific wear rate Vs and sound level of friction Lp



(fretting stroke＝191 μm, 7.2 Hz, 25000 cycles)

Possible mechanism of friction noise



Type of contact point

Effect of types of contact point on μ and Rc

Type of contact point	μ	Rc
① Oxide film / Oxide film	0.33	Low
② Metal / Metal	1.09	Very low
③ Loose particles	0.69	High
④ Glaze oxide / Glaze oxide	0.83	Low
⑤ Glaze oxide / Metal	0.83	Low

Brief Conclusions (1)

1. Certain cycles of fretting are needed to generate friction noise.
2. There are common features in relation to the occurrence of friction noise : drastic reduction in coefficient of friction μ, self-excited vibration and negative gradient of μ.
3. Sound level of friction increases with increase in fretting stroke and frequency, and is directly related to average sliding velocity.
4. There is a good relation between the sound level and amount of wear.

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- ECR under various Lubricants

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- Analysis model
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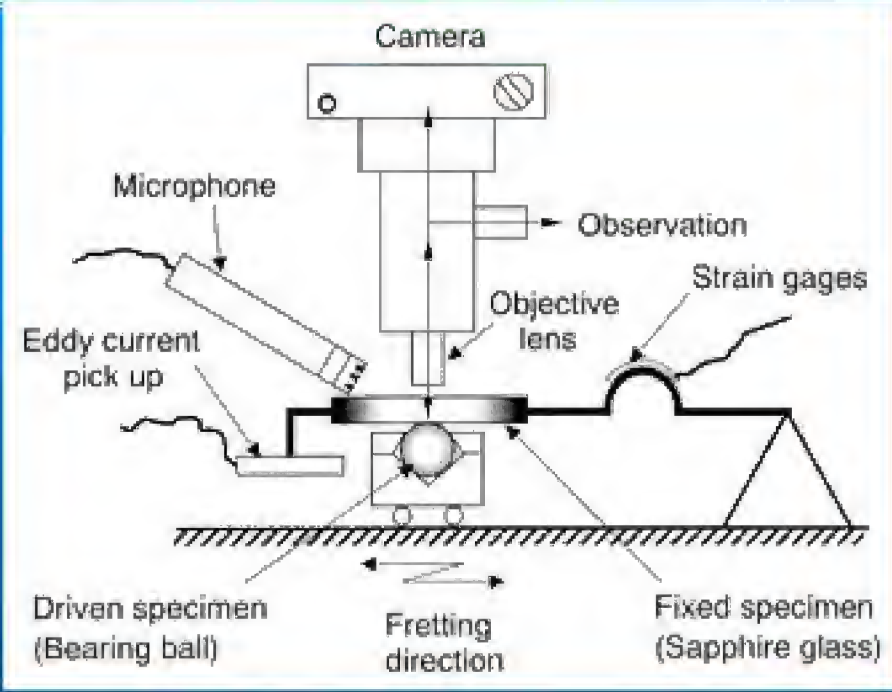
Apparatus



Schematic illustration of direct observation of fretted area

Lubricants

Table Lubricants

Type	Lithium soap grease
Base oil	Mineral oil
Viscosity of base oil	145.4[mm^2/s]@40℃ 14.67[mm^2/s]@100℃
Consistency	285(25℃,60W)
Additive	MoS_2 powder

Fretting test

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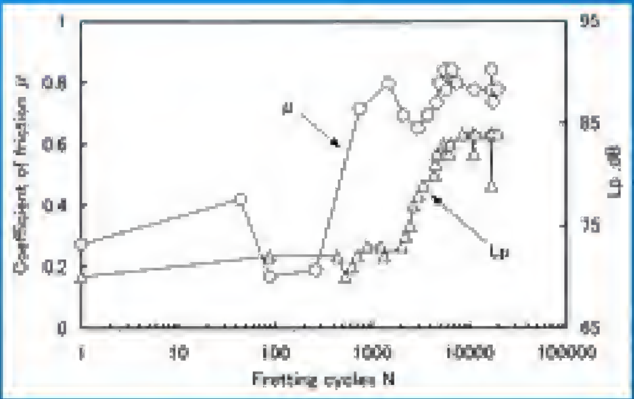
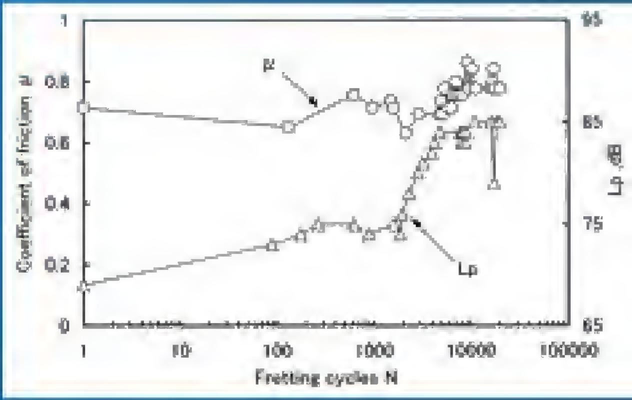
Fretting stroke	25～400 μm
Normal load	19.6N
Atmosphere	Laboratory air, Grease lubrication
Test duration	Up to 10^6 cycles
Frequency	7.3Hz
Temperature	294±2K
Relative humidity	23～80%RH
Data sampling frequency	5kHz (4096data)
Configuration	Crossed cylinders, Ball on plate

Typical results of measurements



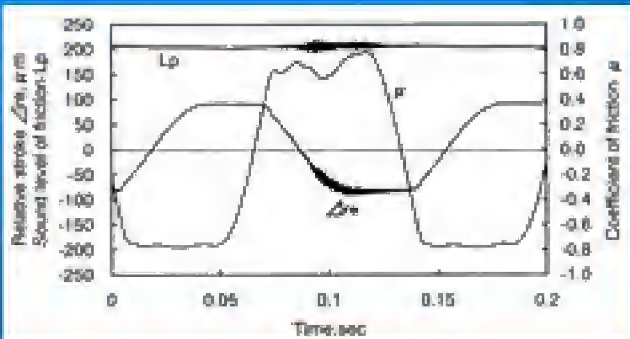
(a) S=130μm, G=6μm



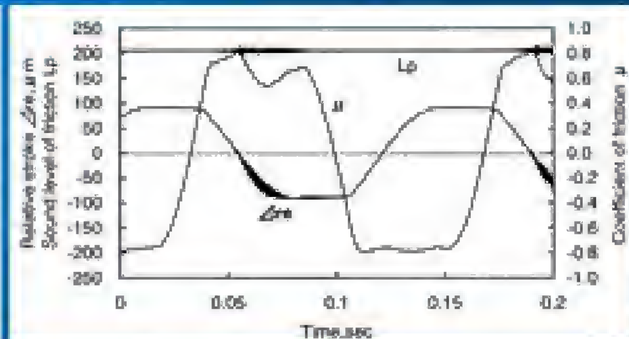
(b) S=130μm, G=0μm

μ and Lp plotted against fretting cycles N

Typical results of measurements



(a) $S=130\,\mu m$, $G=6\,\mu m$, $N=5000$cycles



(b) $S=130\,\mu m$, $G=0\,\mu m$, $N=5000$cycles

Curves of Lp, μ, and ⊿re

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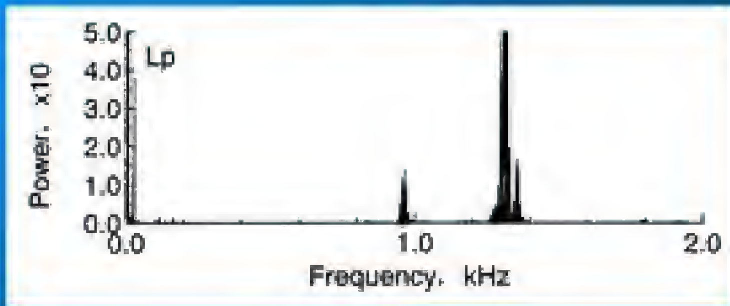
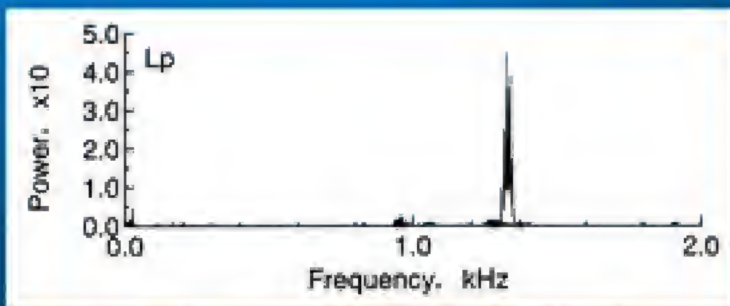
Typical results of measurements



(a) S=130 μm, G=6 μm, N=5000cycles



(b) S=130 μm, G=0 μm, N=5000cycles

FFT analysis of Lp and dI/dt

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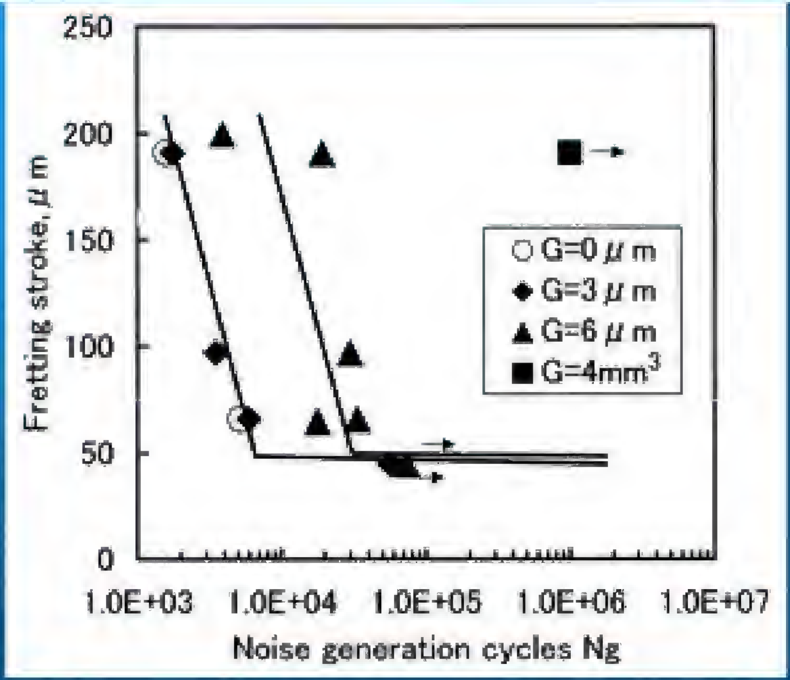
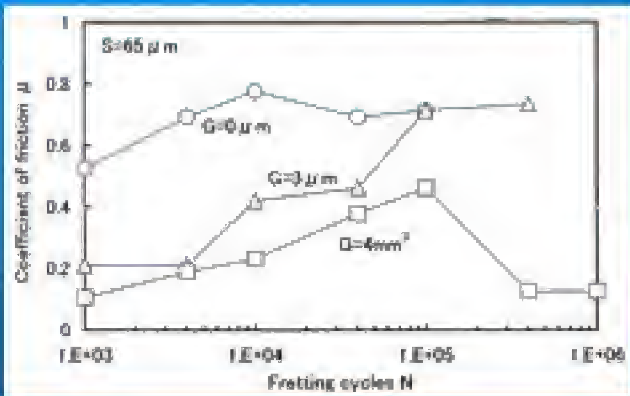
Typical results of measurements

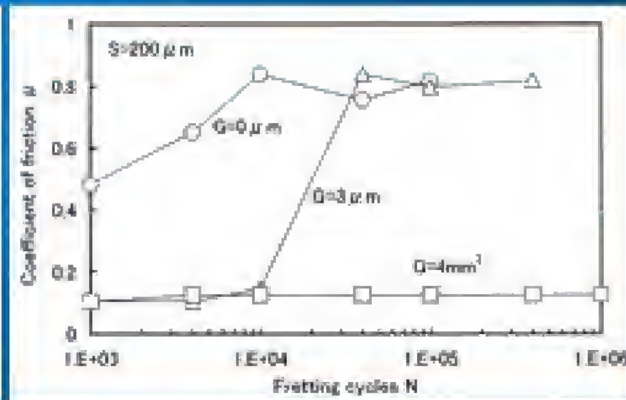


Influence of the amount of grease and fretting stroke on the noise generation cycles Ng

Typical results of measurements



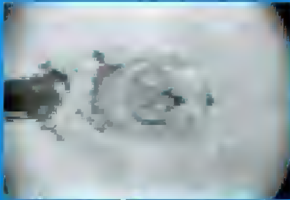
(a) S=65 μ m

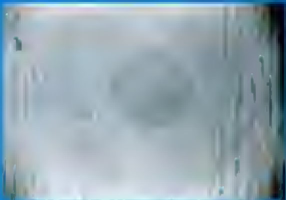


(b) S=200 μ m

Relationship between μ and N

Typical results of measurements


(i) 10^3 cycles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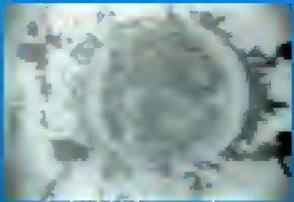
(ii) 10^4 cycles


(ii) 10^4 cycles


(ii) 10^4 cycles


(iii) 10^5 cycles
(a) G=0 μm


(iii) 10^5 cycles
(b) G=3 μm


(iii) 10^5 cycles
(c) G=4mm^3

Direct observation of fretted surfaces

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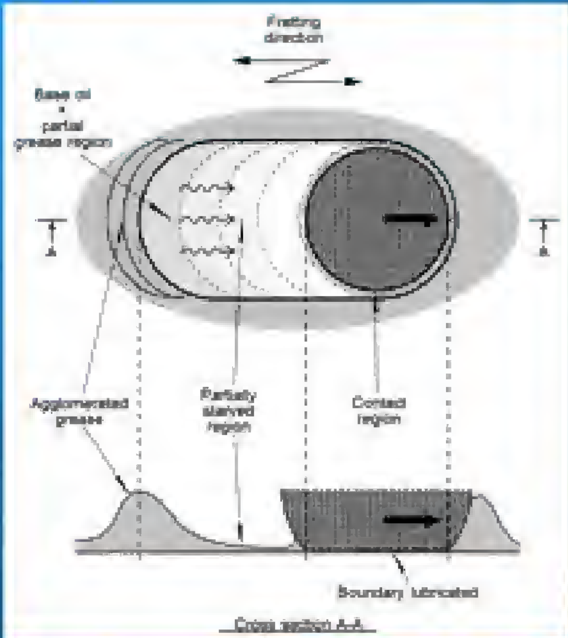
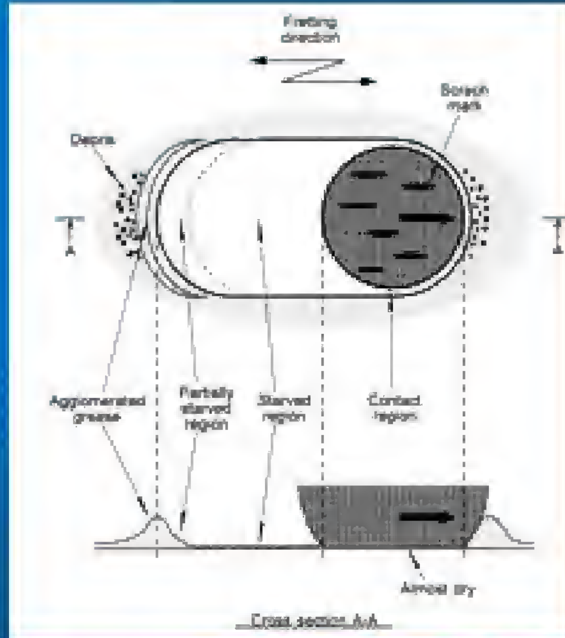
Possible mechanism



(a) Sufficient amount of grease



(b) Small amount of grease

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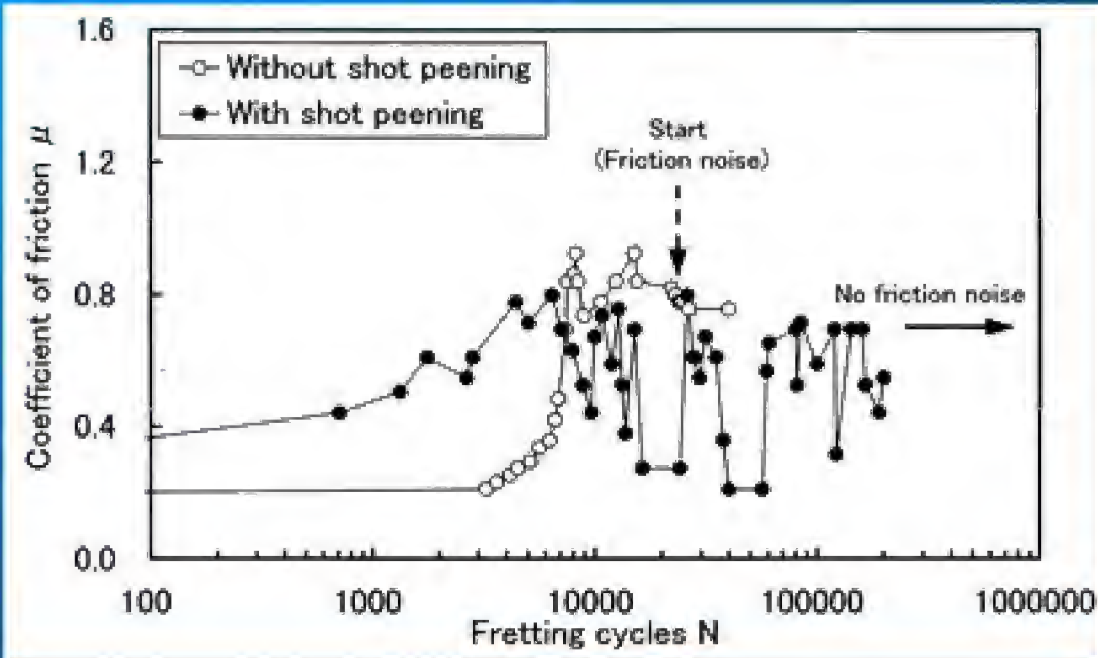
Effect of shot peening



(S=65 μ m, G=6 μ m)

Observation of wear scar with shot peening

(S = 65 μm, G = 6 μm)

(Shot condition : 0.6 mm steal ball, air type pressure = 0.3 MPa, 120sec, arc height = 0.6 mmA, coverage = over 100 %)

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Brief Conclusions (3)

1. The generation of friction noise under grease lubricated condition is greatly affected by the amount of grease supplied and fretting stroke.
2. In the case of a small amount of grease, friction noise similar to that of non-lubricated fretting generates, because once the grease is expelled from the contacting surfaces, it cannot be supplied from around the fretted contact. The worn surfaces are basically the same as those of non-lubricated fretting.
3. In the case of sufficient amount of grease, the friction noise never generated during whole fretting. Because the grease around the fretted surfaces is gradually supplied into the contacting surfaces with fretting action. The coefficient of friction μ is constantly low and fretting wear hardly occurs.
4. Very small holes lying on fretted surfaces such as those by shot peening from "oil pools", and are effective to prevent the friction noise. They gradually supply the lubricants to the fretting surfaces.

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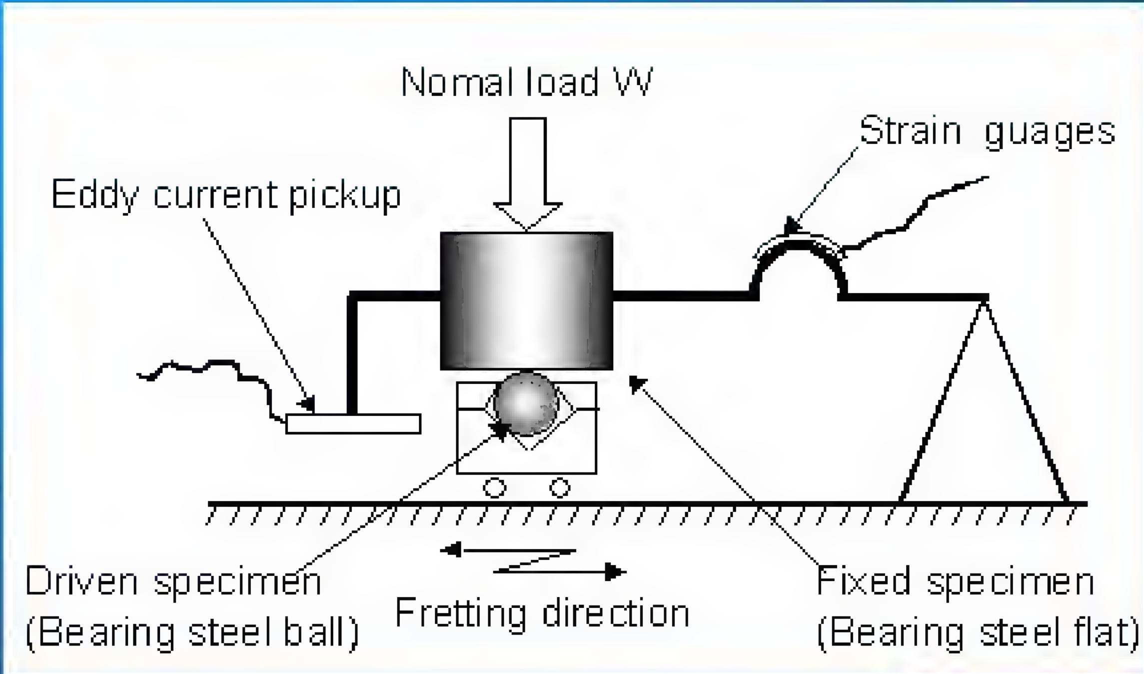
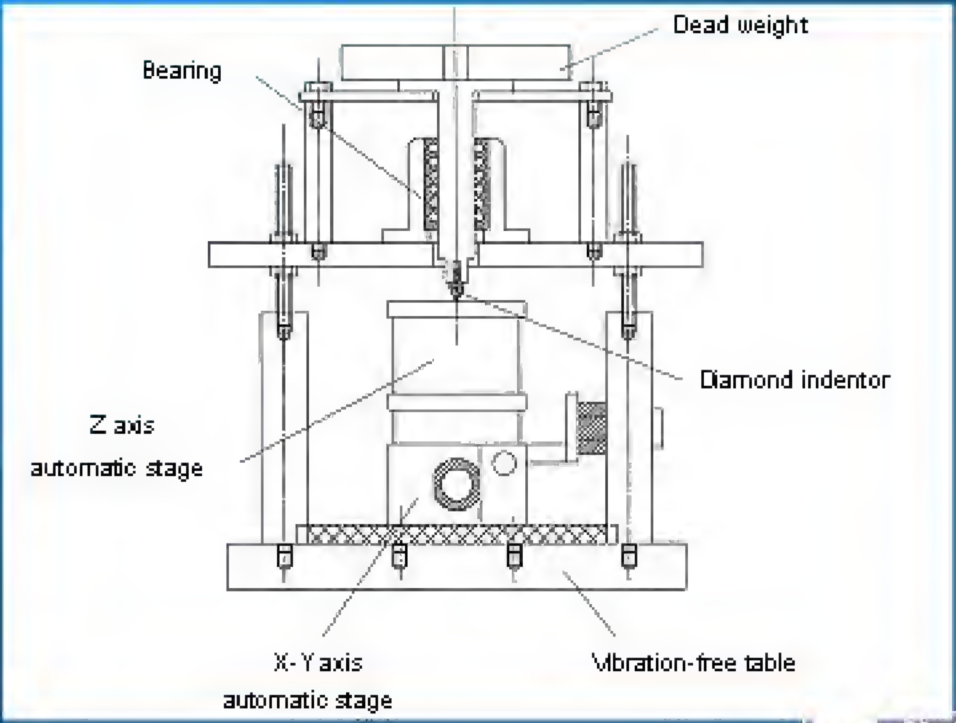
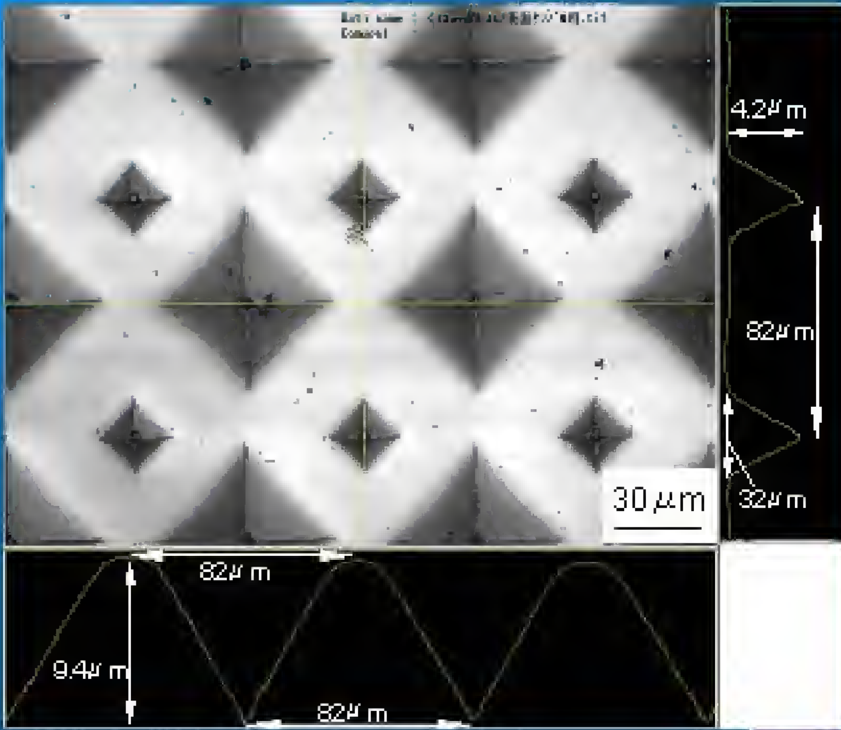
Overview of fretting apparatus



Overview of surface micro fabrication apparatus



Laser microscopic image of micro texturing surface (Dimple pattern)



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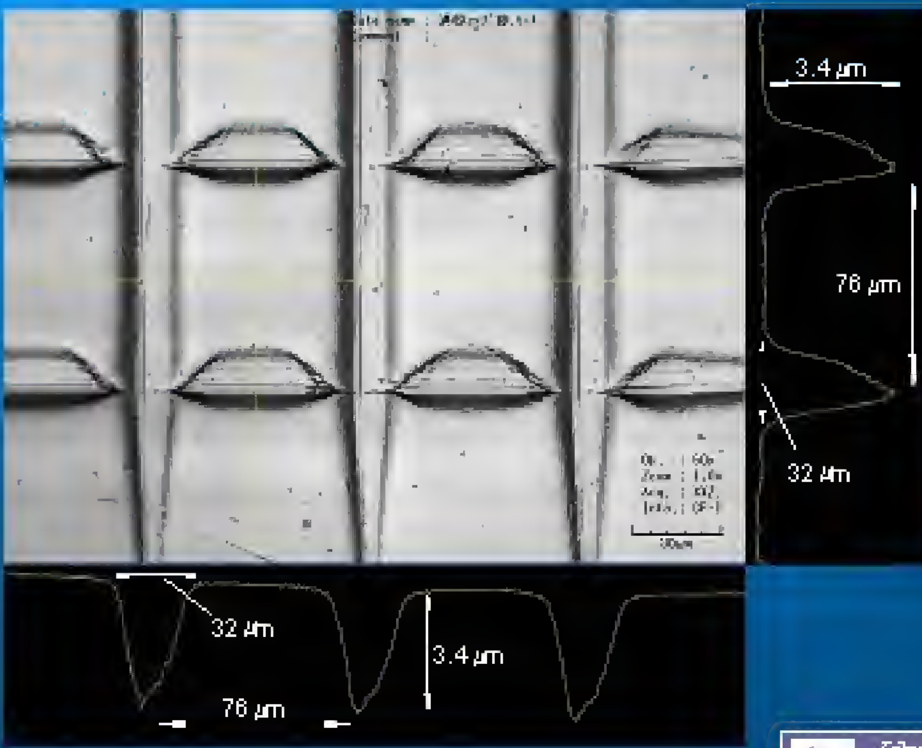
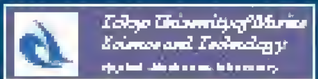
Laser microscopic image of micro texturing surface (Groove pattern)





Experimental condition

Specimen	Fixed	Bearing steel flat (Hv760), ϕ20×20mm
	Driven	Bearing steel ball (Hv760), ϕ9.525mm
Configuration		Point contact (flat/sphere)
Relative stroke		12~215 μm
Normal load		4.9~22.1N
Atmosphere		In air, oil lubrication
Lubricants		350 neutral oil, Kinematic viscosity; 74.72cSt@40℃, 9.26cSt@100℃
Fretting cycles		20× 10^4 cycles
Frequency		7.35Hz
Temperature, humidity		22±3℃, 51±18%

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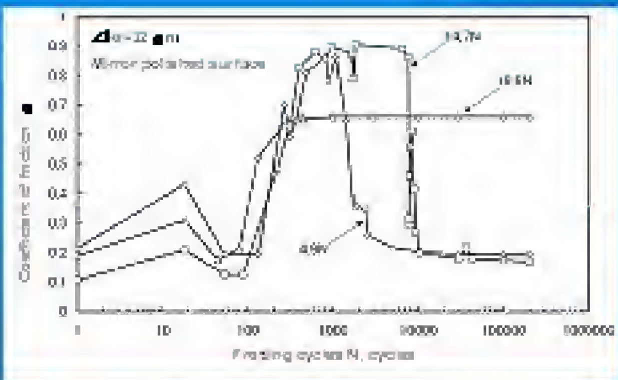
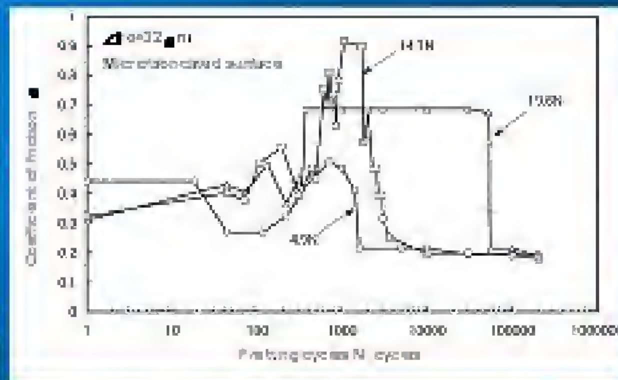
Change in coefficient of friction μ



(a) Mirror polished surface



(b) Microfabricated surface

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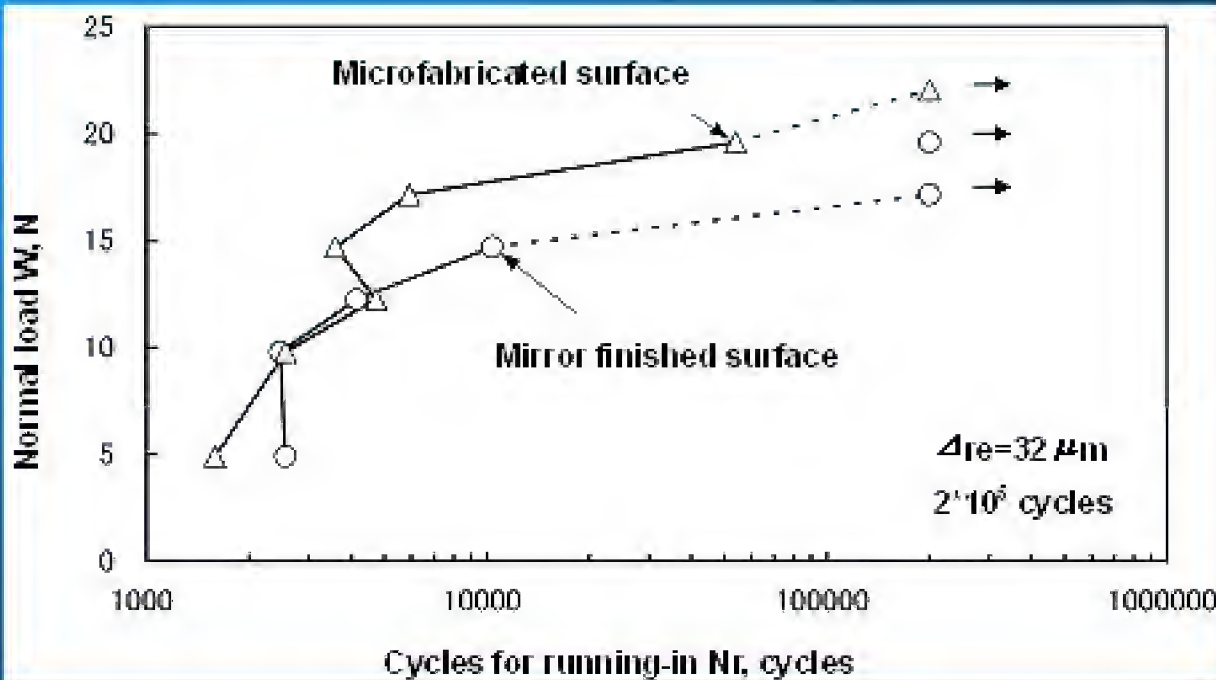
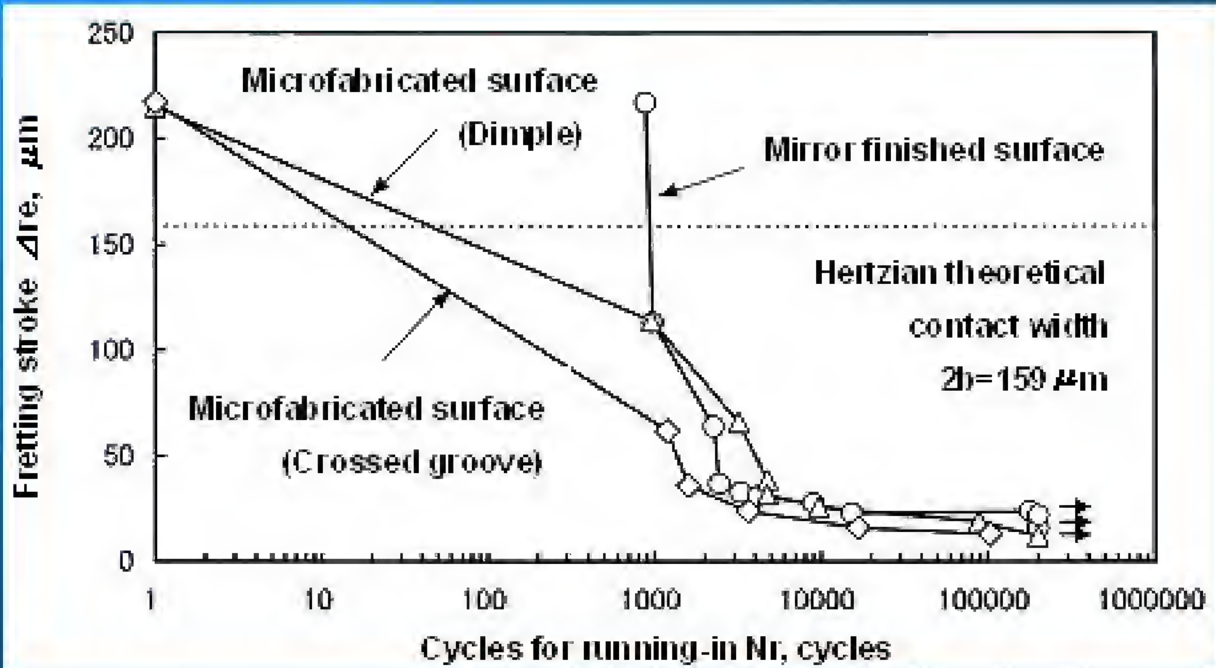
Influence of normal load W

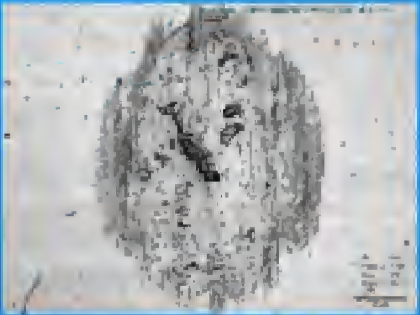


Influence of fretting stroke Δre

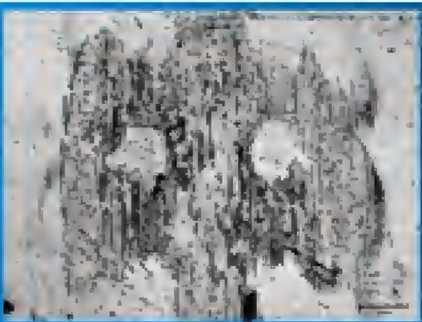


(W=12.3N, 2*10^{5}cycles)

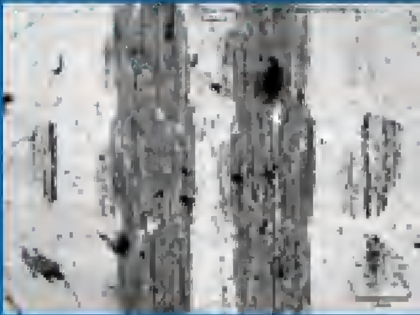
Observation of fretted wear scars



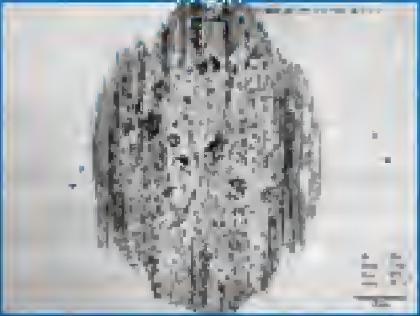
(a) Mirror finished surface (ball)



(c) Microfabricated surface (ball)

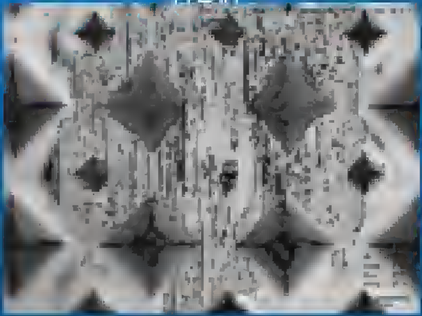


(e) Microfabricated suaface (ball)



(b) Mirror finished surface (flat)

(Wear scar width = 143 μm)



(d) Microfabricated surface (flat)

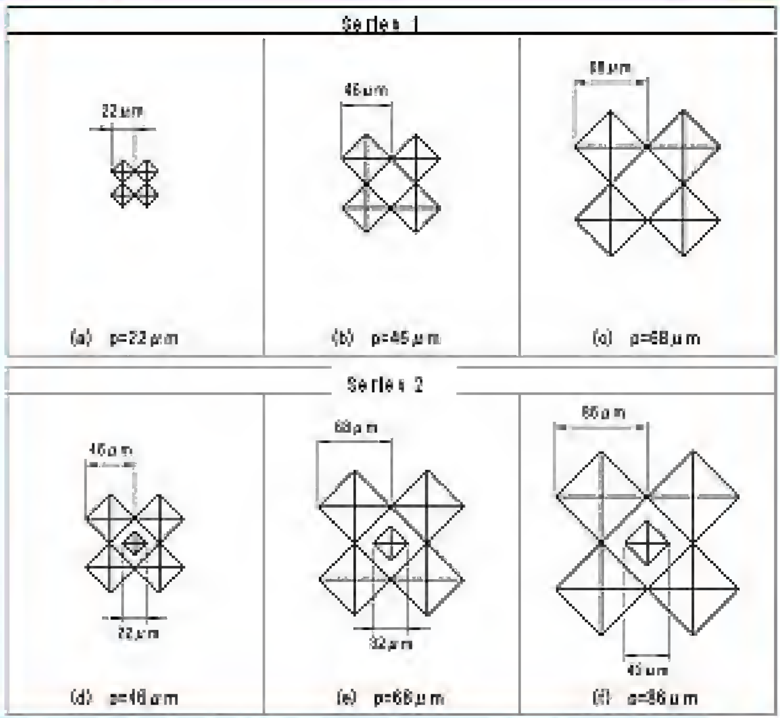
(Wear scar width = 197 μm)

(f) Microfabricated surface (flat)

(Wear scar width = 231 μm)

(Δre=36～39 μm, W=12.3N)

Patterns of micro texturing



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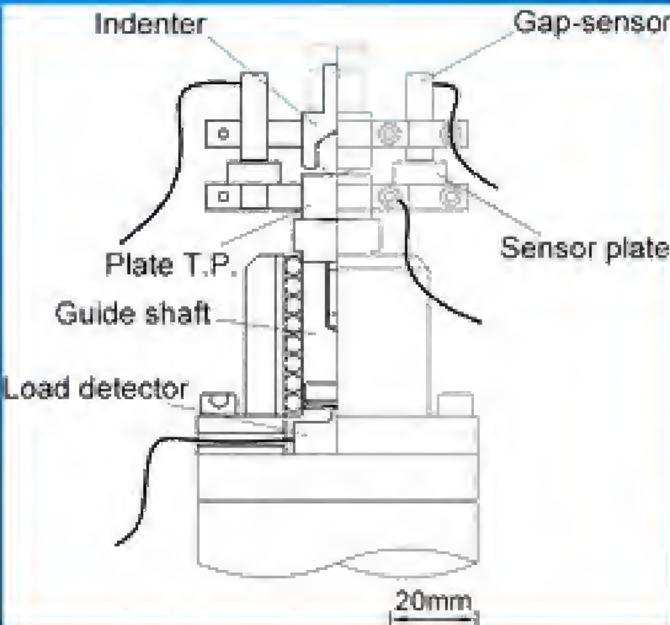
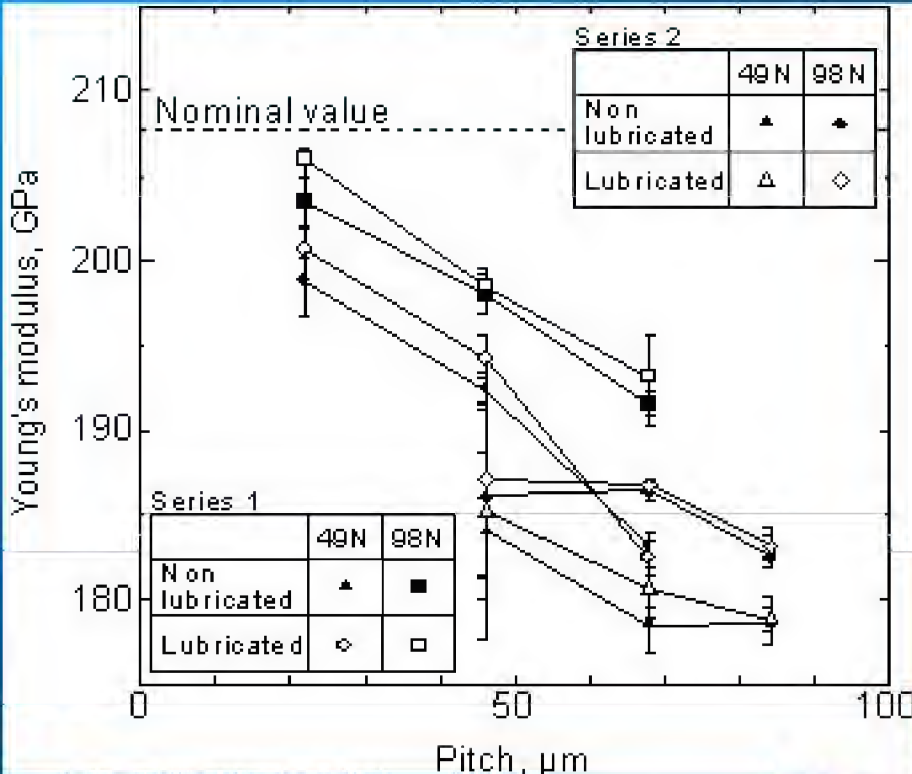
Schematic illustration of Young's modulus measuring apparatus



Contacting stiffness of micro texturing surface



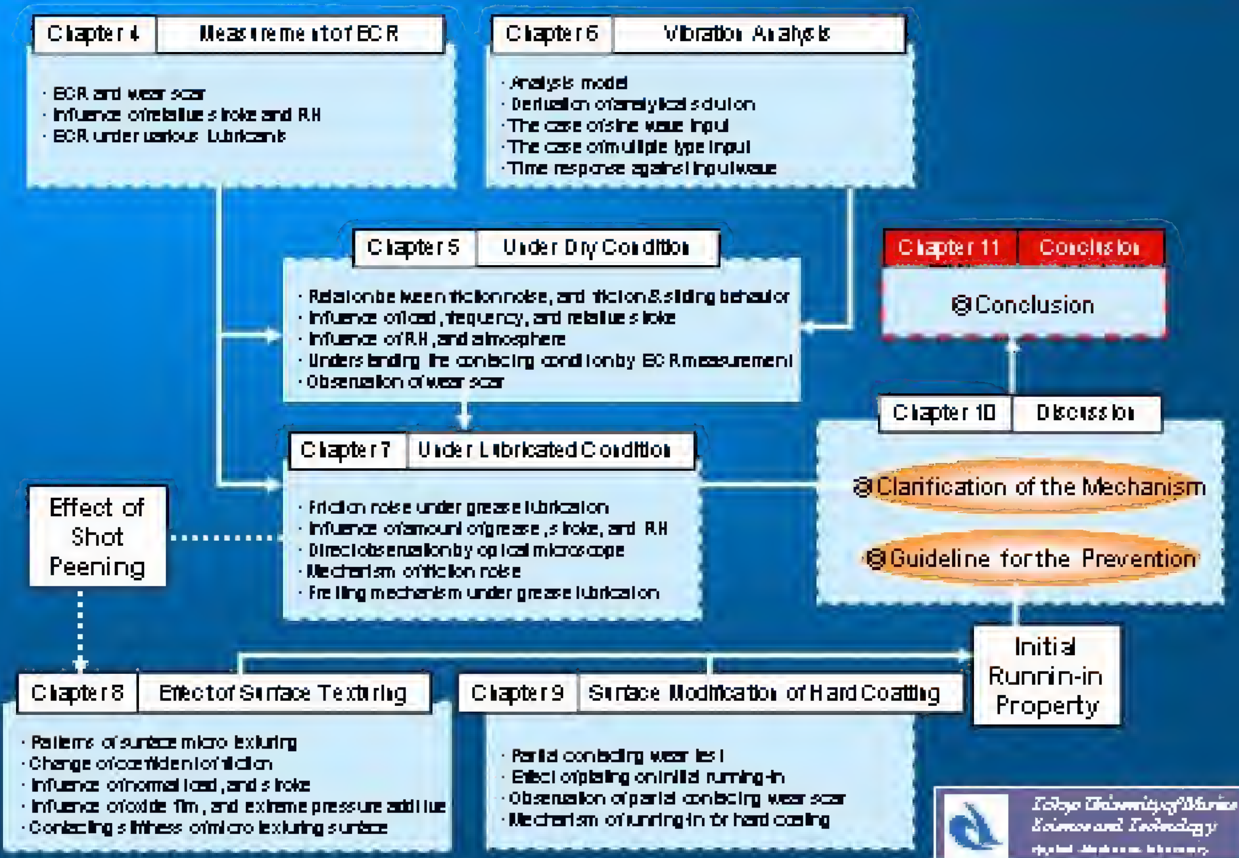
Brief Conclusions (4)

1. The micro texturing surface has an effect to accelerate the initial running-in process compared with that of the mirror finished one.

2. The contacting stiffness of the micro texturing surface is low compared to that of the mirror finished one, and the contact region is larger. The lubricating oil existing in the dimples bears a portion of the contact load.

3. The contact pressure around the dimples, that is, in the plateau regions, is high, and it is still higher at the edge of the contact region. These pressure are higher than the maximum Hertzian contact pressure for the mirror finished surface at the center of the contact region.

Composition of this Study



Conclusions I
Mechanism of friction noise

1. Under the dry condition, certain cycles of fretting are needed to generate friction noise, and there is a close relationship between the generation of friction noise and wear process.
2. When the wear debris is accumulated in the contacting surfaces with the wear progression, types of real contacting point become diverse, and friction behavior easily becomes changeable.
3. When the phenomenon of drastic reduction of μ occurs, it becomes "trigger", and friction noise generates.

Conclusions Ⅱ
Mechanism of friction noise under lubricated condition

1. Under the grease lubricated condition, in the case of sufficient amount of grease, friction noise never generated, however, in the case of a small amount of grease, it cannot be supplied from around the fretted contact, and then it becomes the same as that under the dry condition, finally friction noise generates.

2. The mechanism of friction noise under the lubricated condition is basically the same as that under the dry condition.

Conclusion Ⅲ
Guideline for the prevention of friction noise

1. It takes constant lubricants in the contacting surfaces to prevent the friction noise under the grease lubricated fretting . The effectiveness of "shot peening" was confirmed as one of the example to actualize it.

2. "Micro pools", or "Micro grooves" formation on the surface is effective to prevent the fretting damage, and its effect results in the prevention of friction noise.

Questions and Answers